

**Long-Term Pavement Performance (LTPP) InfoPave:
Extracting Practical Information out of the Data**

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ABSTRACT

Long-Term Pavement Performance (LTPP) InfoPave is the web interface for the world's largest pavement performance database. This web interface is being developed under the Federal Highway Administration (FHWA) LTPP program to achieve the strategic goal of utilizing LTPP data effectively. An effective web interface helps reach users crossing all levels of expertise and geographical boundaries and helps information sharing which adds value to tax payers' dollars.

To overcome the hurdles for easy data access, the initial phase of the LTPP InfoPave development considered effective ways of data design including organizing the data for the user, expanding data to the unit (test section) level, developing consistent terminology and metadata, and using familiar pavement engineering names for tables and fields in the database. The design of the data warehouse and development of feature mechanisms were centred on the efficient data structure model.

Feedback obtained at each major step of development helped create this web interface. LTPP InfoPave, released during the 93rd annual meeting of the Transportation Research Board (TRB) in January 2014, has received positive response from students, researchers, State DOT engineers, and stakeholders alike. The second release of InfoPave in January 2015 includes major enhancements to existing features and a series of new features, which implement novel visualization tools to further facilitate access to LTPP data.

The application of LTPP InfoPave enhances data visualizing, selection, and access. This paper will layout data analysis examples, which demonstrate the utility of InfoPave in providing answers to pavement performance questions. Plans for future improvements and implementation will be discussed as well.

INTRODUCTION

The LTPP program was envisioned as a comprehensive program to satisfy a wide range of pavement information needs. It draws on technical knowledge of pavement engineering currently available and seeks to develop models that will better explain how pavements perform. It strives to gain knowledge of the specific effects on pavement performance of various design features, traffic, environment, materials, construction quality and maintenance practices. Over the past 25 years, the LTPP program has accumulated a large amount of data, as well as a mass of documentation and related tools. These data, documentation, and related tools comprise the comprehensive LTPP Information Management System (IMS). The LTPP IMS consists of the following:

- Pavement Performance Database (PPDB)
- Ancillary Information Management System (AIMS)
- Reference Library (RL)

The LTPP database was designed for collection and storage of data regarding construction, maintenance, and performance of test sections. Complying with that design concept, the tables and fields within the database have coded names and numerous codes for various data elements. This information is difficult to access for the user. For example, if the user wanted to find data about joint sealant, there are multiple tables from which to pull sealant information based on the experiment type and whether the sealant was applied during construction or during a maintenance event.

For each test section, the data collected over time is stored into various modules, which are a combination of multiple tables. In addition, there are multiple levels of data including section level and project level, and multiple levels of quality, for example test data have higher quality than inventory data tables. The user needs additional time to learn and account for these factors.

Dissemination of the information to the public has been difficult due to the complexity of the data structure and organization, as well as the sheer amount of data available. There are few new users of the data because the novice researcher does not understand where even simple information might be stored. The LTPP program has experienced a continuing need for improved public access and understanding of LTPP data, as well as the necessity to keep up with the latest information technology.

The InfoPave project was initiated to develop, enhance, maintain, and support an effective web interface program for the LTPP IMS. The goal of InfoPave is to get a complete and relevant set of user selected data to the user effectively and efficiently. In order to meet the goals, the elements of both the latest technological advancements and an understanding of the LTPP program goals was necessary. A team of professionals from iEngineering, Fugro, Pennsylvania State University, and Woodward Communications was selected to perform this task. This team devised a plan to accomplish project objectives through the following main steps:

- **Terminology:** providing user-friendly pavement engineering titles for tables and fields
- **Classification:** providing the user with a simplified structure of data classifications that are relevant to their interests with easy to understand terms
- **Expansion:** populating section level data based on available project-level data sources
- **System Design:** implementing a data warehouse and Data Bucket
- **Features:** displaying the information meaningfully using multiple InfoPave features

- **Technology:** using advancements in technology and infrastructure in delivering the data

INFOPAVE 1.0: DESIGN FOR ACCESS

In an attempt to make the user experience more intuitive, a data classification process was conducted which organizes the complete database by key recognizable characteristics that allow the user to easily navigate to specific information. To prevent the user from getting overwhelmed in details and branching information, the identification hierarchy was limited to three category levels. The primary category is a broad description of the type of data and includes Referential, Construction, Climate, Traffic, Maintenance & Rehabilitation (M&R), and Performance. Secondary and tertiary levels further identify the types of data available, with the tertiary level representing a small group of data that is easily sortable.

Similarly, classifying the vast amount of LTPP data into a simpler data structure (data classifications) is the key in making the same data meaningful to the user. The user-friendly field names, defined terms, and industry familiar data structure will eliminate most of the hurdles that the user currently has in accessing the LTPP data.

With data expansion, data is available at a section level. For example, traffic and climate data that are available for a site are now available for each and every test section within that site. Expansion will also eliminate the need for the user to be familiar with the operational data structure. The user won't need to know which specific types of data are available to download at section-level. This will also simplify data access and use.

In computing, a data warehouse (DW) is a database used for reporting and analysis. Implementation of a data warehouse was a key component of the LTPP InfoPave system design strategy. This data warehouse leveraged proposed data classification to simplify raw data (PPDB and AIMS). The data warehouse architecture is based on a relational database management system server that functions as the central repository for informational data.

A data warehouse consists of metadata, data summaries, and raw data. Metadata is used for building, maintaining, managing and using the data warehouse. The single most dramatic way to affect performance in a large data warehouse is to provide a proper set of aggregate (summary) records that coexist with the primary base records. The main objective when designing summary tables is to minimize the amount of data being accessed and the number of tables being joined. Actual raw data should be kept alongside, or within, the data warehouse itself, thereby enabling the construction of new and different representations. LTPP IMS is raw data (source data). The illustration in FIGURE 1 shows the relationship of LTPP IMS data and the LTPP InfoPave data warehouse.

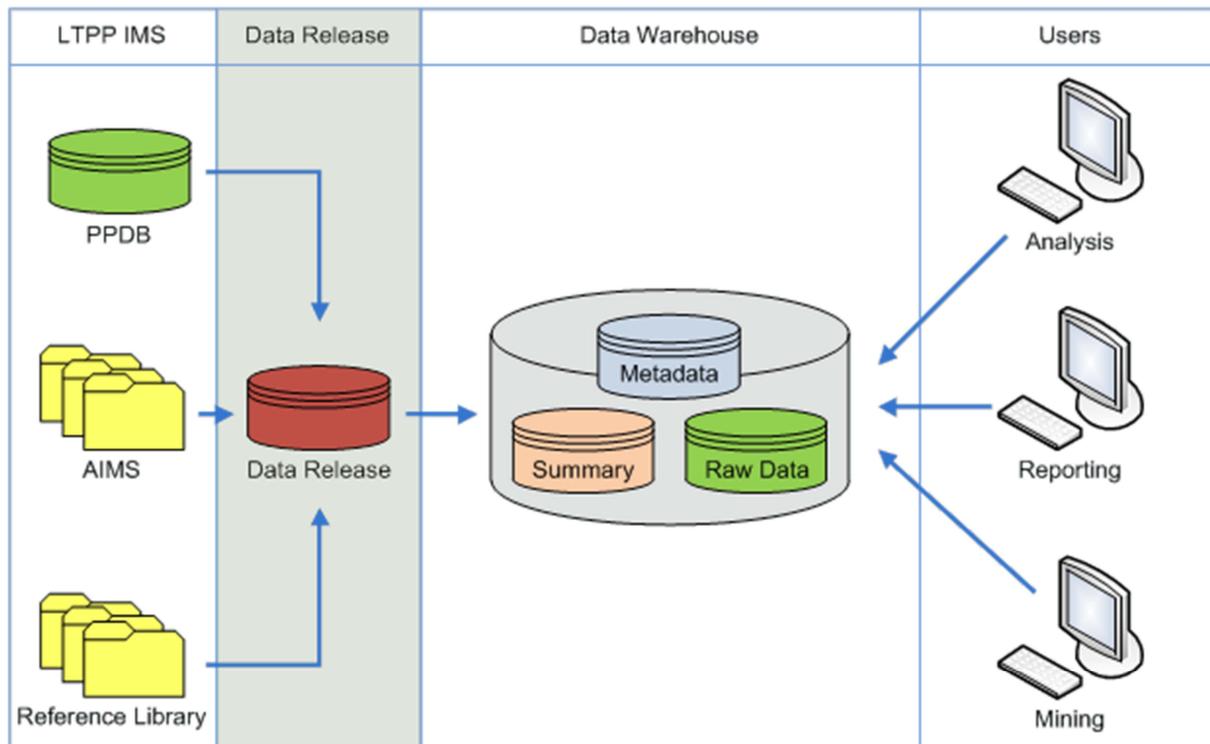


FIGURE 1 LTPP InfoPave Data Warehouse

LTPP InfoPave provides features that are needed to view, access, select and obtain LTPP data. Different view functionalities including the map, pivot, graphs, and timelines, help select the right section(s) for further review or analysis. Selection of data can be done using a filtering function to narrow down the set of available experiment sections to only those which fit certain criteria. The Section Summary Report, Section Timeline, and Data Pivot features provide overview information of the selected sections.

After overview and selection of the appropriate sections, the user will have the ability to export the data through the Data Hub. The user can select the desired tables and fields through the Data Selection and Download feature. This is one of the main features in the InfoPave public facing interface. It allows the user to see different data classifications and select the data in default (basic) view. The user is given advanced view options to see data fields with their respective tables so they can select any/all fields in a given table. The user can then add selected data to their Data Selection list that will later be submitted to the Data Bucket for extraction. In addition, the more experienced user will be able to export IMS tables using the Table Export feature or through the SQL server command window.

To provide examples of direct application of the available LTPP data, online tools have been developed which can be populated with the LTPP data to return useful results such as the Mechanistic-Empirical Pavement Design Guide (MEPDG) Inputs, Performance Forecasting, and Rigid Pavement Design. Separately, downloadable tools for further interpretation and application of LTPP data are available which allow the user to predict Dynamic Modulus and select asphalt binders based on performance criteria.

INFOPAVE 2.0: ENHANCED FEATURES FOR DATA ACCESS

After the alpha and beta releases of InfoPave and following the launch of InfoPave 1.0, numerous suggestions were made to enhance the user experience and further facilitate access to LTPP data. Along with improvements made to the data structure, website infrastructure, administration interface, and mobile interface, the following key enhancements were implemented for the public facing interface of InfoPave 2.0:

1. **Advanced Filters:** Data filters allow end users to narrow down the pavement sections according to defined parameters. Titled “Find Sections,” this is a core feature of InfoPave that is available on multiple views. The implemented enhancements to this feature include cascading the filters combined with options to choose “and/or” selection criteria while filtering. In addition, the advanced filters will include sub-filters and additional data attributes for section selection.
2. **Data Selection and Download:** Enhancements to this feature include Data Preview, which allows the user to preview the data before adding it to a Data Bucket, and data source colour scheme, which gives the user the option to see the source of the available data tables. The improved Data Bucket provides an option to convert the units of the numerical data within the selected tables, and an option to include descriptions corresponding to fields containing codes within the downloaded tables.
3. **Interactive Help:** An Interactive Help tool provides step-by-step guidance to the novice InfoPave user. At this phase, this interactive help has only been implemented in the Data Selection and Download feature, one of the most frequently used InfoPave features. This guided tour provides instructions at each step, allowing the user to provide feedback and select desired data for download.
4. **Visual Data Selection and Download:** These topic-specific interfaces allow one-stop access to structure, traffic, climate, and performance data. Each interface displays the available data elements in an interactive graphical platform. By clicking on each data icon in this platform, the user will have access to data source and data availability. For example, FIGURE 2 illustrates the interface for climatic data. Clicking on the “precipitation” icon displays the group of related LTPP tables for each data source (collected or calculated), and indicates the number of sections (out of the selected sections filtered using the “Find Sections” feature) for which the selected table(s) are available to be downloaded.

FIGURE 2 Visual Data Selection and Download

5. Section Summary Report: This feature has been enhanced from its previous design to include additional time series graphs, visualizing LTPP data trends with time. In addition, the improved feature includes functionality to display time series graphs for multiple test sections at a time, providing a visual comparison of the long term performance of up to four different pavement structures. FIGURE 3 shows the comparison graph for the progression of measured fatigue cracking on four different LTPP asphalt concrete (AC) test sections.



FIGURE 3 Section Summary Report

6. **Section Timeline:** Timeline displays the chronological history of section events that consist of maintenance/rehabilitation and monitoring activities. Previously, this feature only allowed users to view distress maps and images. Implemented enhancements to Section Timeline enable users to view data for all events such as distress surveys, inspection videos, climatic and traffic data.

7. **Pavement Cross-Section Viewer:** Pavement layer information following different construction events is currently only available in data format. Pavement Cross-Section Viewer allows users to visualize pavement layer structure data. As depicted in FIGURE 4, this new feature displays layer information dynamically through pavement age to compare various construction events.

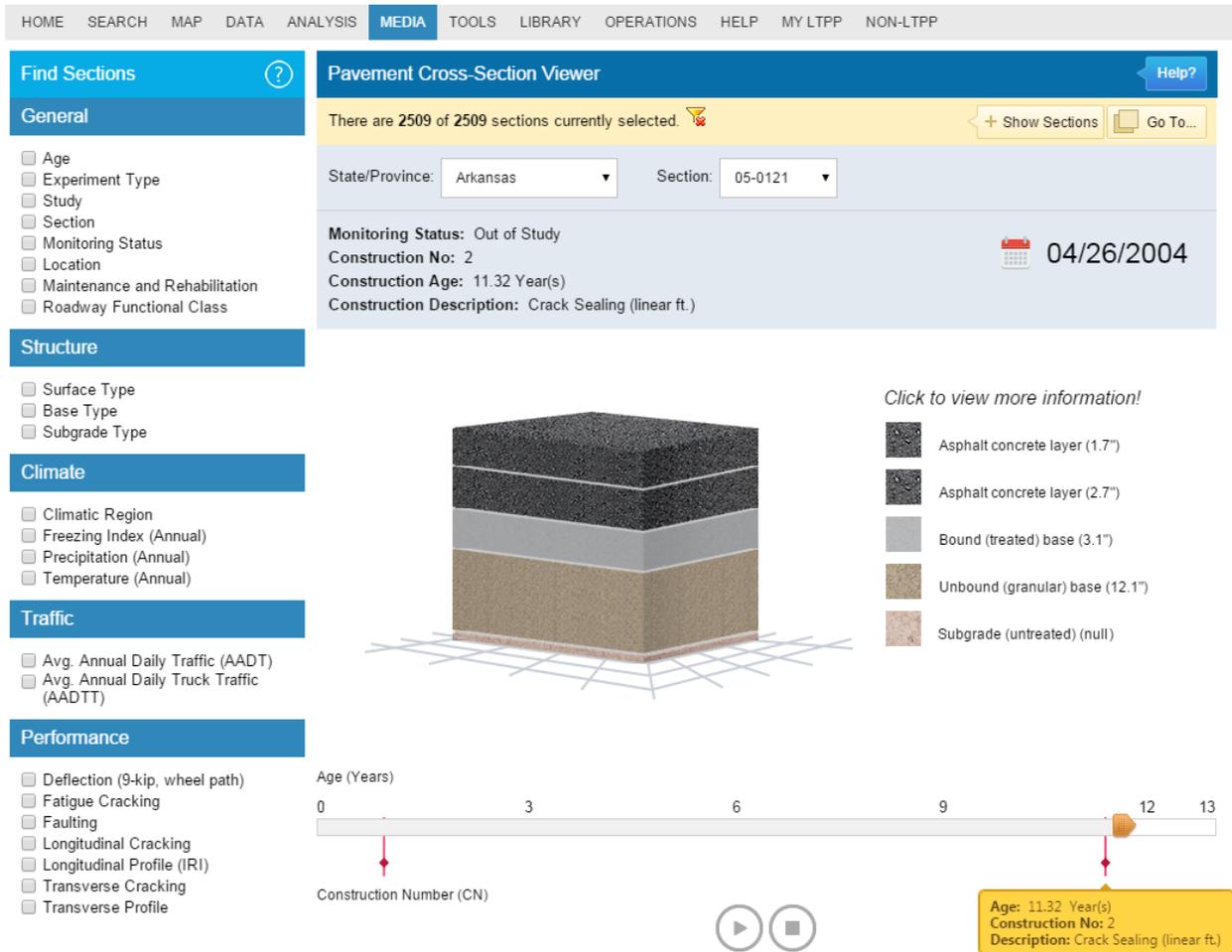


FIGURE 4 Pavement Cross-Section Viewer

8. **Distress Viewer:** Distress maps are already available for sections on the LTPP InfoPave Media Hub. Users can view these maps individually but there is no comparison feature available that would allow visualization of distress over a period of time. Enhancements to this feature are implemented to help the user view distress maps for any section over a time slider. Multiple distress maps are available for each section collected during multiple distress surveys. As indicated in FIGURE 5, Distress Viewer will allow users to compare different distresses from various survey dates on one segment of a test section.

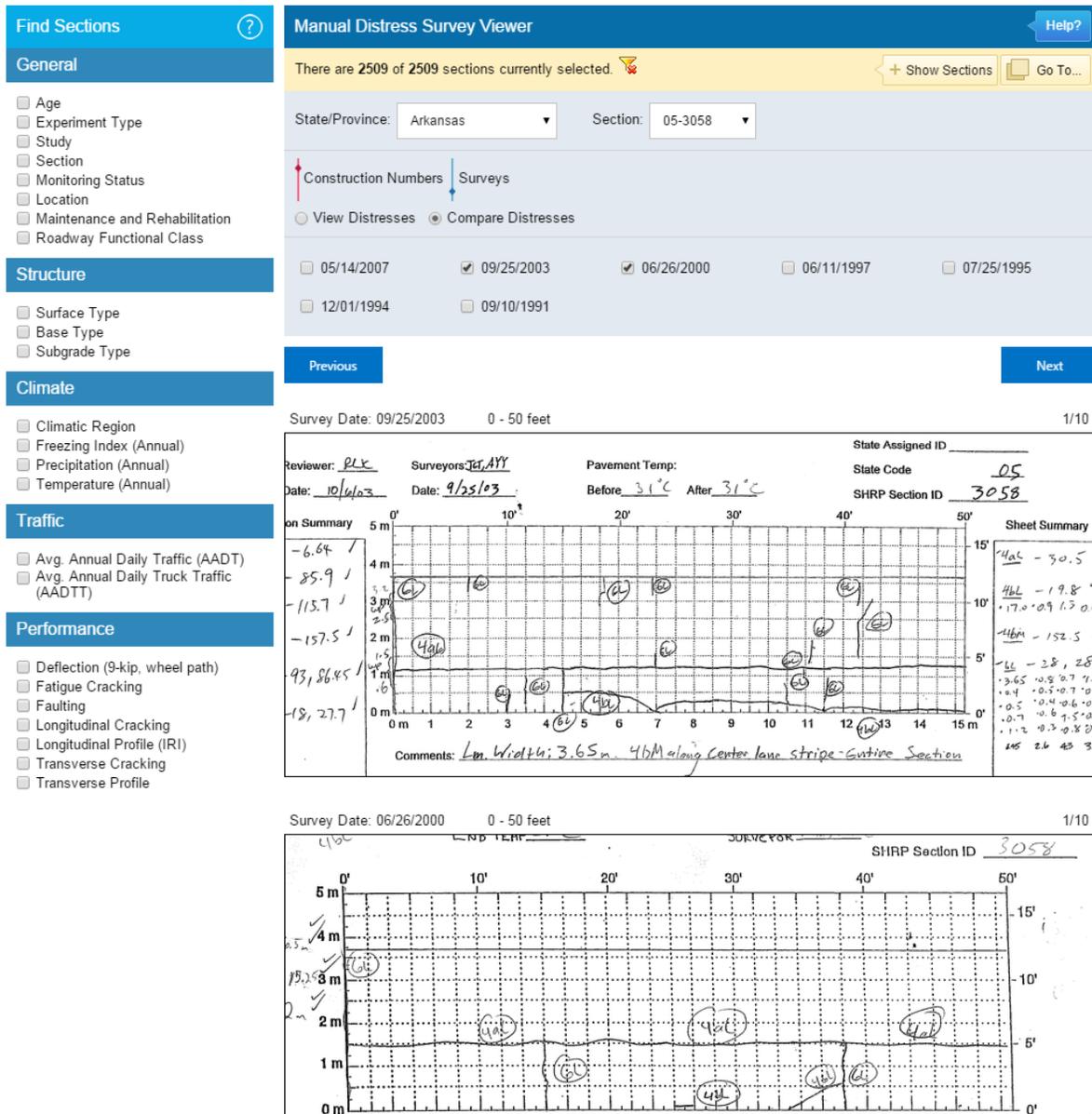


FIGURE 5 Pavement Distress Viewer

9. **Geospatial Analysis:** Google Maps is used in LTPP InfoPave for geographical representation of data. In the new release, the map feature has been enhanced to provide support for geospatial analysis. This new feature is developed to select data elements for display on Google Earth style maps. The option to export data in Keyhole Markup Language (KML) has also been provided.

10. **Find LTPP Research:** The new Analysis Hub includes a feature for finding LTPP research reports. LTPP data have been used in various research analyses. Developed based on the LTPP Strategic Data Analysis Plan (I), this feature classifies the available research reports according to the topic, study objectives, and the sponsoring agency.

EXTRACTING INFORMATION OUT OF DATA

LTPP InfoPave provides various tools and features that facilitate selection and extraction of LTPP data for further analysis. As indicated in FIGURE 6, InfoPave facilitates data analysis in terms of finding the desired data, getting the data and sharing it with colleagues and collaborators, and preliminary analysis of the data.

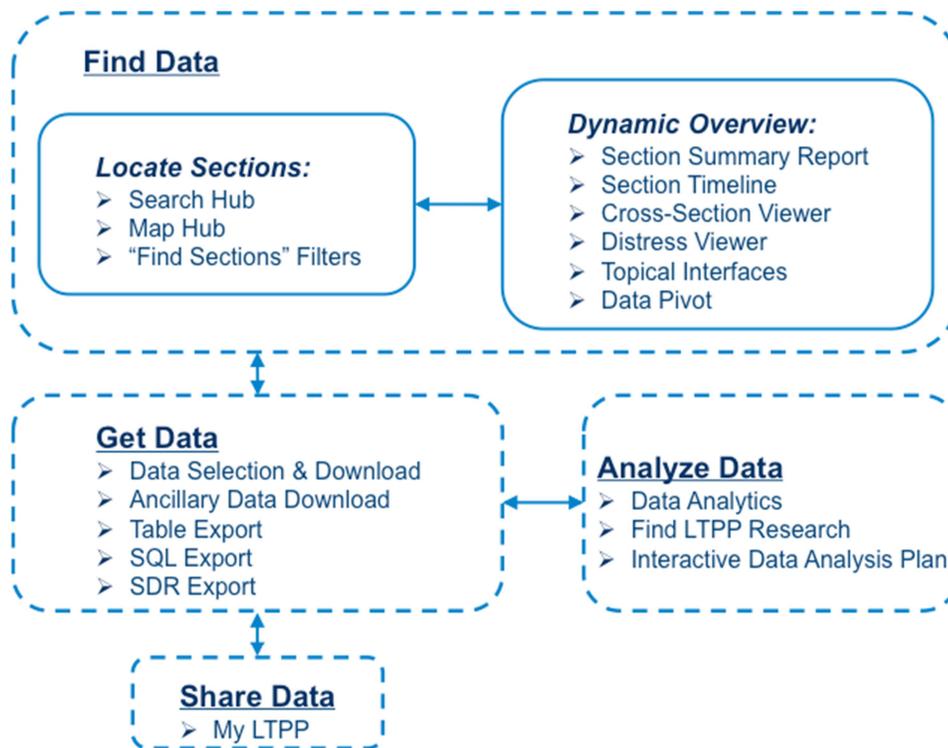


FIGURE 6 Extracting LTPP Data Using InfoPave

The user can locate the desired LTPP sections using the Search and Map Hubs and narrow down the search utilizing the "Find Sections" filters. Several dynamic visualization features provide basic overview of the data to ensure that the selected subset of LTPP sections is suitable for carrying out the intended analysis. Once the user is confident with the selected sections, the actual tabulated LTPP data can be downloaded using a variety of tools. A link to the final set of selected data can be shared with other colleagues and collaborators.

The set of features in the new Analysis Hub provide access to the relevant research available in the literature. This preliminary review can provide valuable insight into the problem at hand, place it within the context of the state of the art, and guide the possible solution approaches.

In this paper, two examples are demonstrated using the LTPP InfoPave web portal to study pavement performance for use in performance management. In the first example, the effect of various rehabilitation treatments on asphalt concrete (AC) pavement performance is investigated. LTPP specific pavement study, SPS-5, compares sections in a site which have been overlaid with various thicknesses of virgin and recycled AC following differing levels of surface preparation. Comparing roughness progression trends on various sections of one site would evaluate the relative effect of different rehabilitation treatments on pavement performance.

It is assumed that the user is interested in a SPS-5 site that has less than 1,000 trucks per day on average and is located in a wet–no freeze climate. Using the “Find Sections” filters allows the user to find the available sections meeting these criteria (FIGURE 7). Out of these sections, nine comprise the core sections of the SPS-5 site in Oklahoma.

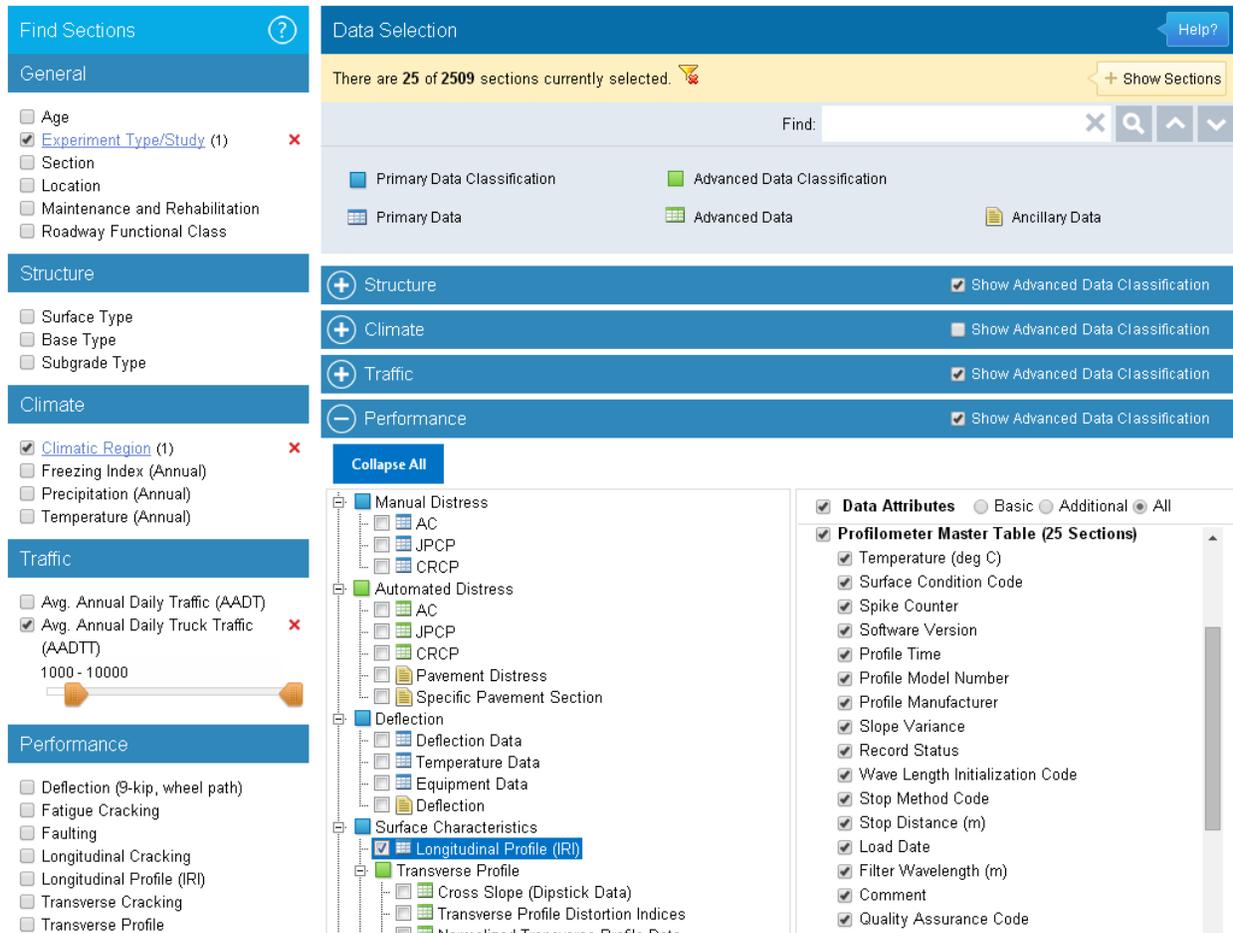


FIGURE 7 Using Data Selection and Download

Selecting the “Longitudinal Profile” table (from the Performance group of tables) will add the LTPP MON_PROFILE_MASTER table which includes International Roughness Index (IRI) data. The user does not need to know the unfamiliar name of the corresponding LTPP table. In the downloaded Excel file, each worksheet includes the selected tables individually. In addition to the main tables, Table Reference, Field Reference, and Code Reference worksheets are included to explain the type of data contained in these tables and fields, and the meaning of the Codes used in them.

FIGURE 8 shows the IRI values for each survey date on the nine core sections within the Oklahoma SPS-5 site. The decrease in roughness due to rehabilitation and the roughness progression trend after each type of rehabilitation can be investigated in this graph. As expected, the control section which has received no overlay has the highest amount of roughness increase rate. It is also evident that the milling of the existing surface followed by thicker asphalt overlays has resulted in the lowest IRI progression rates.

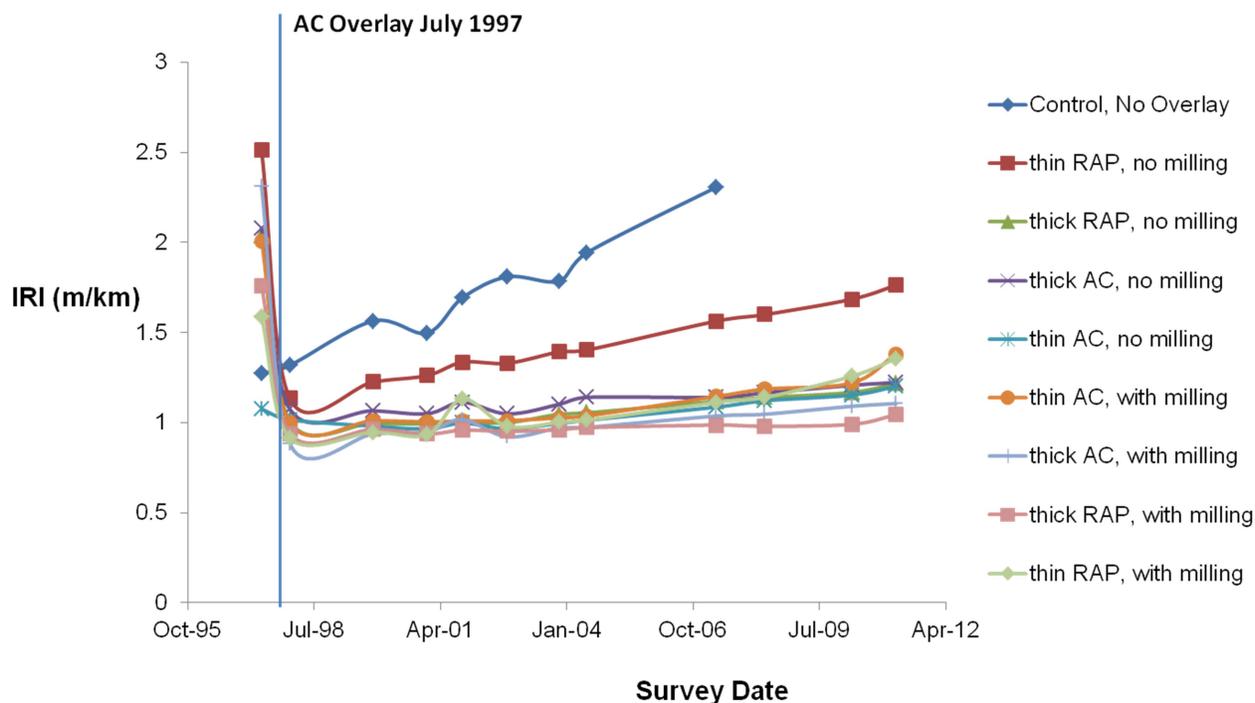


FIGURE 8 Roughness Progression Trends on LTPP SPS-5 Site in Oklahoma.

As the second example, transverse cracking patterns are investigated on jointed plain concrete pavements (JPCP) with varying structural parameters. The LTPP SPS-2 pavement study compares sections in a site which have been constructed with various thicknesses of concrete and base layers. Comparing cracking progression trends on sections of one site would evaluate the relative effect of different structural parameters on pavement performance.

It is assumed that the user is interested in a SPS-2 site in Michigan. Using the “Find Sections” filters can lead the user to the 12 core sections on this site. Selecting the “Manual Distress” table for JPCP will add the LTPP MON_DIS_JPCC_REV table which includes the transverse cracking data. In addition to this table, the “Representative Pavement Structure” table contains the LTPP TST_L05B table which includes the thickness and material type for each pavement layer. Again, it should be noted that the user does not need to know the unfamiliar names of the corresponding LTPP tables.

FIGURE 9 shows the percentages of section slabs cracked transversely for each survey date on the Michigan SPS-2 site. These percentages are calculated based on the downloaded data. In this figure, DGAB stands for dense-graded aggregate base, LCB for lean concrete base, and PATB for permeable asphalt-treated base. The varying levels of cracking on each concrete pavement with various structural parameters can be investigated in this graph. As expected, the seven inch concrete slab on LCB has experienced a higher amount of transverse cracking as it has a significantly lower thickness compared to other sections.

Similarly, FIGURE 10 shows the IRI trends on the Michigan SPS-2 site. It seems that the concrete slabs on PATB have lower IRI increase rates with time. This could be attributed to the permeable base which facilitates drainage for these test sections.

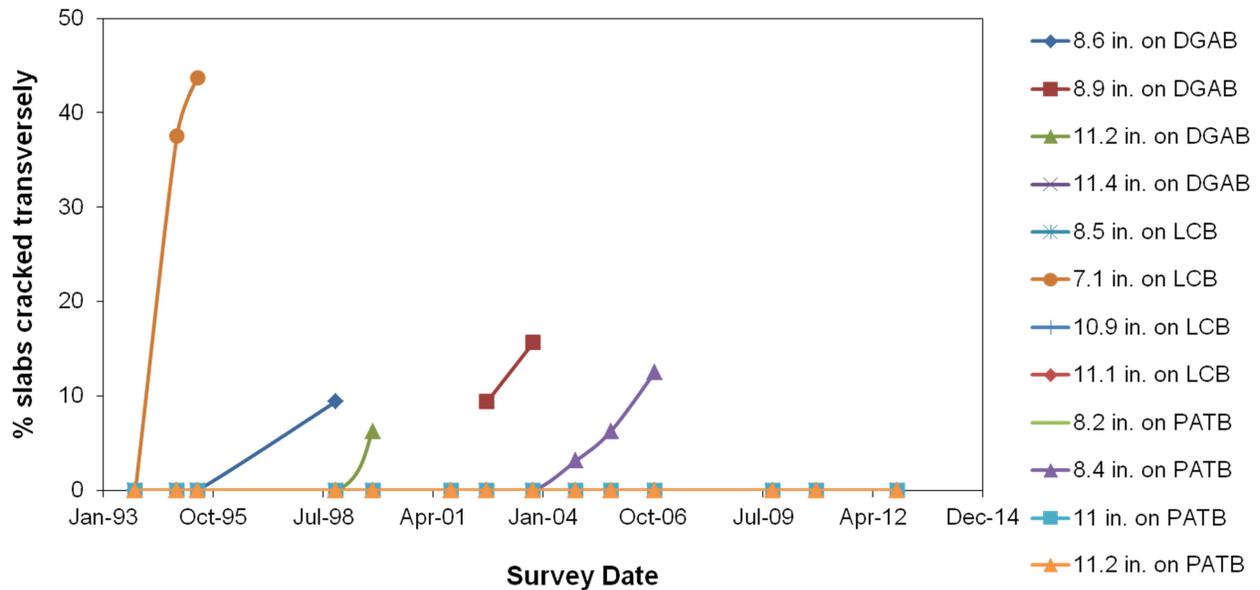


FIGURE 9 Percentages of slabs cracked transversely on LTPP SPS-2 site in Michigan.

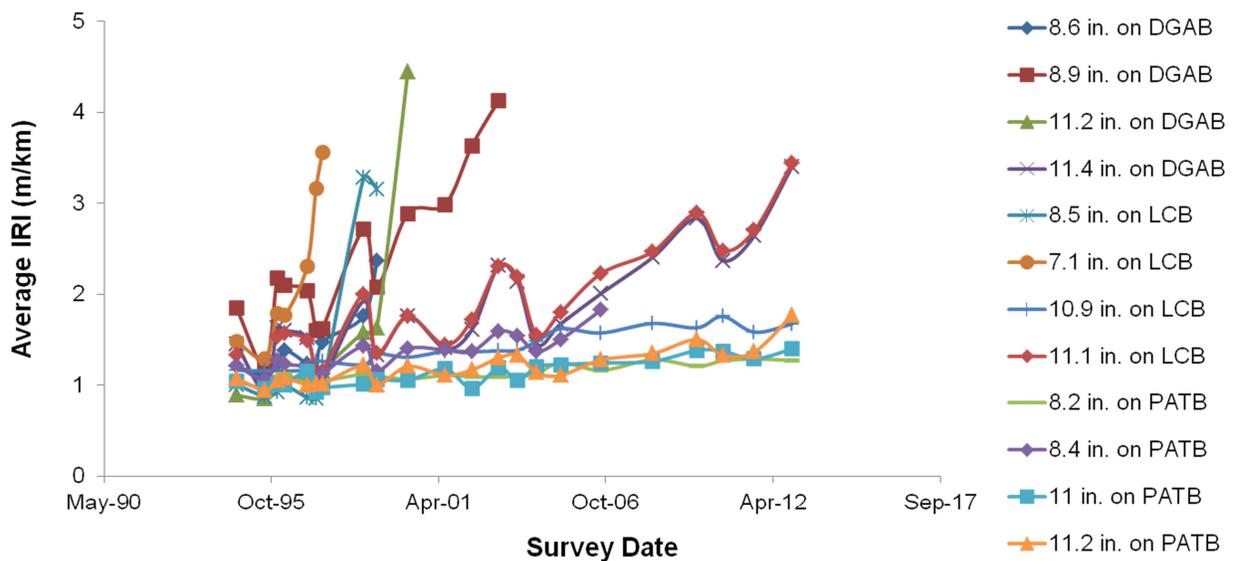


FIGURE 10 Roughness progression trends on LTPP SPS-2 site in Michigan.

Such analyses enable roadway agencies to make an informed data-driven decision on alternative pavement construction and treatment practices that would maximize long-term performance of the highway infrastructure, while minimizing overall costs. This is in line with the performance-based management concept emphasized in the Moving Ahead for Progress in the 21st Century (MAP-21) act.

INFOPAVE FUTURE POSSIBILITIES

As noted previously, LTPP InfoPave was initiated to facilitate access to the wealth of data collected by LTPP and increase the value of the data by making it easier to use in future investigations and analyses of pavement performance. The next few paragraphs will briefly touch on some of the ideas being considered to highlight the possibilities for the future.

The first anticipated enhancement includes additional tools for data visualization. The more tools that can be provided for graphing, displaying, comparing or simply understanding what data exists, the more useful LTPP InfoPave becomes. For many users, quickly reviewing existing data in a clear and concise fashion is the extent of their need.

The next enhancement includes providing tools to facilitate more detailed analysis. Analysis tools may include ready to use data sets or data sets from previous studies, additional access to related studies and/or tools for supporting the processing of the data.

The third enhancement includes providing tools for supporting the collection of similar or related data. This could include tools for collecting and/or processing distress, profile, Falling Weight Deflectometer (FWD) or other pavement performance data.

Another enhancement includes the ability to provide access to other pavement performance data sets in conjunction with the wealth of data available through LTPP. This data augmentation has currently been implemented on a limited scale for the Canadian LTPP (C-LTPP) database but if successful, could be expanded to provide pavement analysts access to a multitude of other regional or local, and long-term monitoring or accelerated testing data sets for supplementing evaluations.

These are only some of the enhancements currently being considered and discussed. The LTPP Team is seeking input from the transportation community to continue expanding the value of the data collected and the LTPP Program.

REFERENCES

1. Strategic Plan for LTPP Data Analysis. FHWA.
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